# Digital Elevation Models of Fort Bragg, California:
## Procedures, Data Sources and Analysis

Prepared for the Pacific Marine Environmental Laboratory (PMEL) by
NOAA National Geophysical Data Center (NGDC)
January 2012

Love M.R.[1], D.Z. Friday[1], P.R. Grothe[1], K.S. Carignan[1], B.W. Eakins[1], and L.A. Taylor[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder
[2]NOAA, National Geophysical Data Center, Boulder, Colorado

*Corresponding project contact:*
Lisa A. Taylor
NOAA, National Geophysical Data Center
Marine Geology and Geophyisics Division
325 Broadway, E/GC 3 Boulder, Colorado 80305
Phone: 303-497-6767
Fax: 303-497-6513
E-mail: Lisa.A.Taylor@noaa.gov
http://www.ngdc.noaa.gov

# Contents



# List of Figures



# List of Tables

# Digital Elevation Models of Fort Bragg, CA: Procedures, Data Sources and Analysis

## 1. Introduction

In January of 2012, the National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), developed bathymetric–topographic digital elevation models (DEM) of Fort Bragg, CA (Figure 1). Two 1/3 arc-second[1] DEMs referenced to mean high water (MHW) and North American Datum of 1988 (NAVD 88) were carefully developed and evaluated. The 1/3 arc-second MHW DEM will be used as input for the Method of Splitting Tsunami (MOST) model developed by the Pacific Marine Environmental Laboratory (PMEL) NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/) to simulate tsunami generation, propagation and inundation. The DEM was generated from diverse digital datasets in the region (grid boundary and sources shown in Figures 2 and 3). The DEM will be used for tsunami inundation modeling, as part of the tsunami forecast system Short-term Inundation Forecasting for Tsunamis (SIFT) currently being developed by PMEL for the NOAA Tsunami Warning Centers. This report provides a summary of the data sources and methodology used in developing the Fort Bragg DEM.

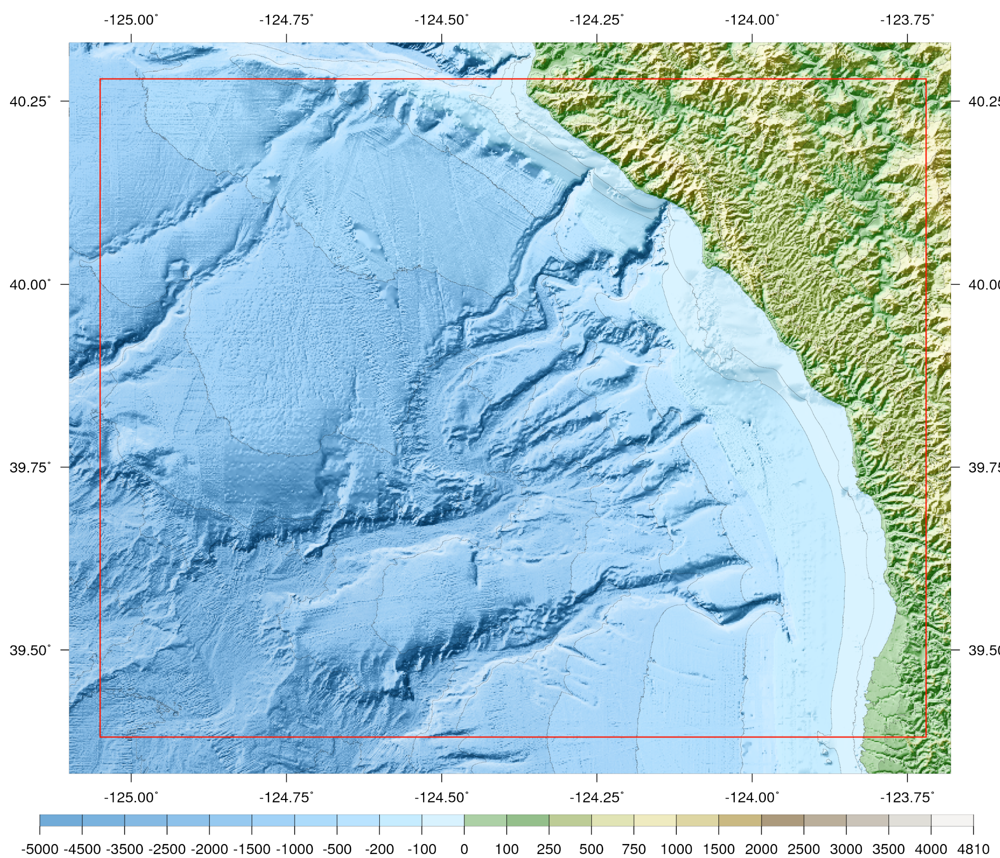


**Figure 1.** *Shaded relief image of the Fort Bragg DEM.*

[1] The Fort Bragg, CA DEM is built upon a grid of cells that are square in geographic coordinates (latitude and longitude), however, the cells are not square when converted to projected coordinate systems, such as UTM zones (in meters). At the latitude of Fort Bragg, CA, 1/3 arc-second of latitude is equivalent to 10.29556 meters; 1/3 arc-second of longitude equals 7.95 meters

## 2. Study Area

The Fort Bragg DEM covers the region surrounding Fort Bragg, California (Figure 2), including portions of Mendecino County and Humboldt County, located in northern California. Notable geographic features in the region include Noyo Harbor, Noyo Canyon, numerous state parks as well as the communities of Fort Bragg, Hardy, Thorn Junction, Riverdale, and Westport, among others.

**Table 1. Specifications for the Fort Bragg DEM**

| | |
|---|---|
| **Grid Area** | Fort Bragg, CA |
| **Coverage Area** | -125.05 °, 40.38 °, -123.72 °, 39.28 ° |
| **Coordinate System** | Geographic decimal degrees |
| **Horizontal Datum** | North American Datum of 1983 (NAD 83) |
| **Vertical Datum** | MHW |
| **Vertical Units** | Meters |
| **Grid Spacing** | 1/3 arc-second |
| **Grid Format** | ESRI Arc ASCII grid |

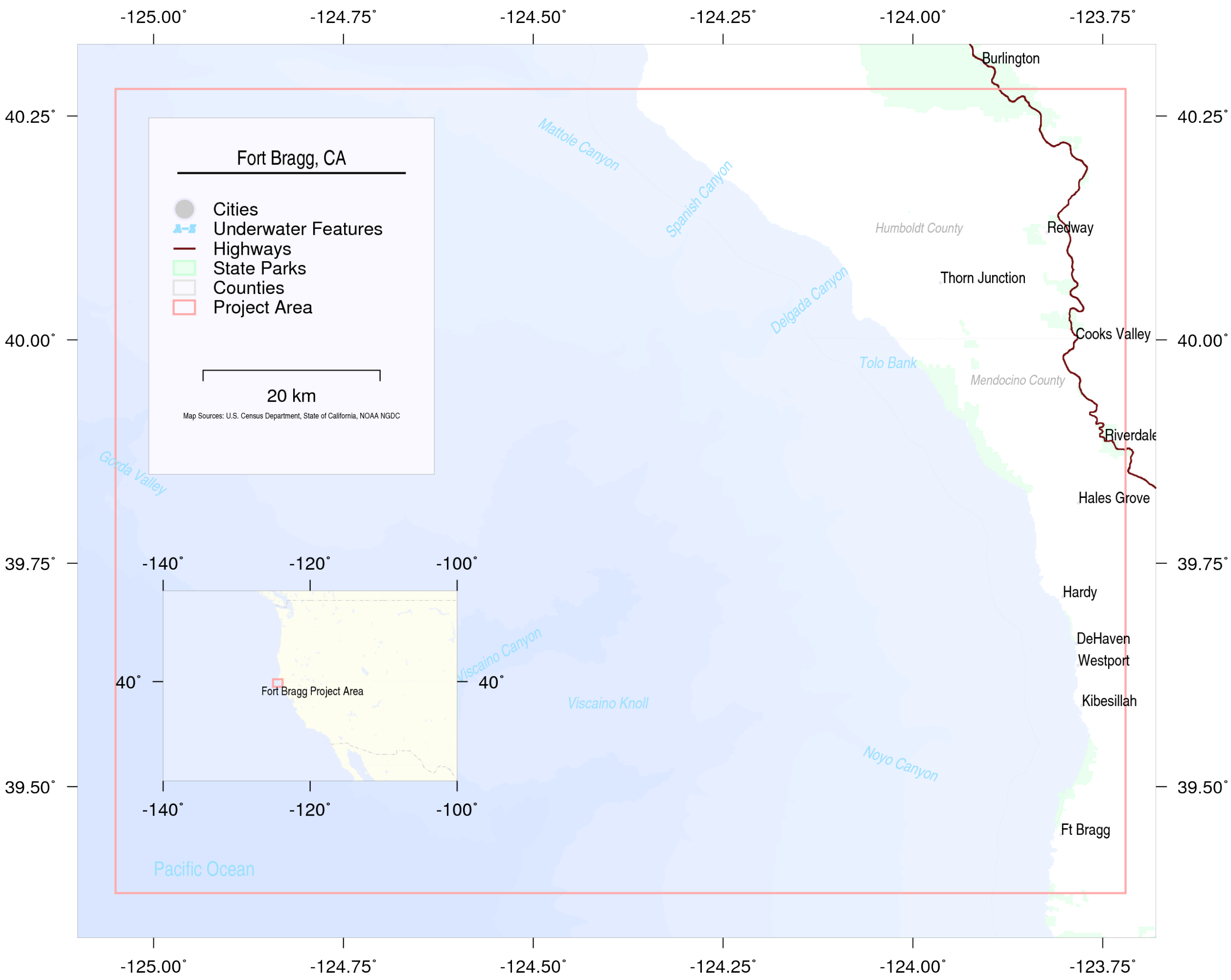


**Figure 2.** *Overview map illustrating the extents of the Fort Bragg DEM*

## 3. SOURCE ELEVATION DATA

The best available digital data were obtained by NGDC from several U.S. federal agencies: NOAA's NGDC and Coastal Services Center (CSC), and the United States Geological Survey (USGS). Data were gathered in an area slightly larger (∼5%) than the DEM extents. This data 'buffer' ensures that gridding occurs across rather than along the DEM boundaries to prevent edge effects. Data processing and evaluation, as well as DEM assembly and assessment are described in the following subsections.

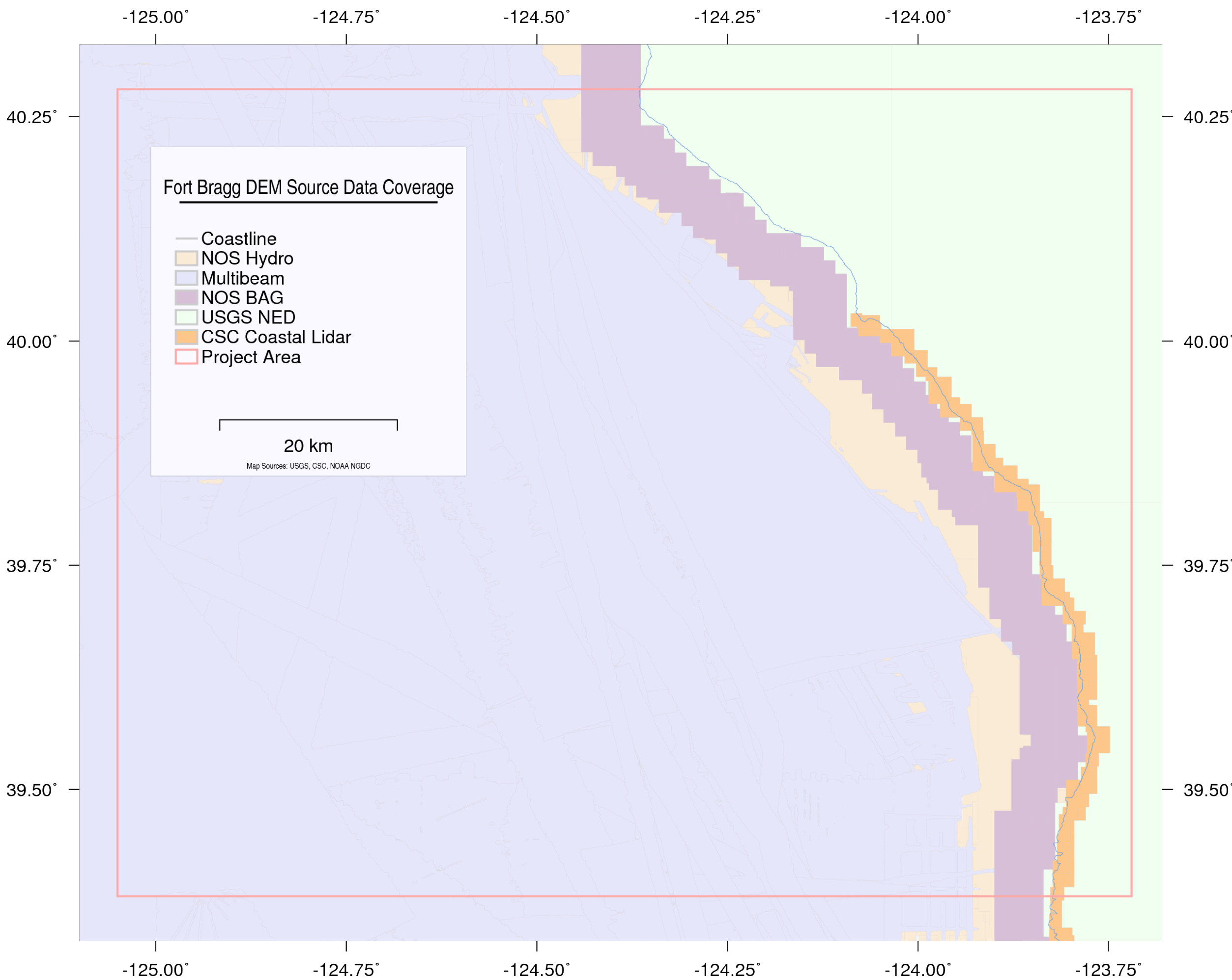


**Figure 3.** *Data sources in the Fort Bragg region.*

## 3.1 Data Sources And Processing

Coastline, bathymetric, and topographic digital datasets (Tables 2, 3, 4 and 5; Figures 3 and 4) were obtained by NGDC and shifted to common horizontal and vertical datums: NAD 83 geographic[2] and MHW, respectively. The datasets were assessed to determine data quality and were manually edited where needed. Vertical datum transformations to MHW were accomplished using a conversion grid developed using NOAA's *VDatum* software package (Section 3.2.2).

### *3.1.1 Coastline*

Coastline datasets of the Fort Bragg region were obtained from a variety of sources. The main dataset used in developing a combined, detailed coastline was the zero-line contour extracted from the coastal lidar datasets (Table 2, Figure 3). This dataset provided a detailed MHW coastline of the Fort Bragg region. NGDC evaluated but did not use the NOAA Office of Coast Survey (OCS) coastline.

The zero-line contour coastline was edited by NGDC using ESRI World Imagery to better represent the coastline immediately sourrounding bays and inlets and to ensure the resolution of the breakwaters in the region, which were not adequately represented in other data sources (Figure 4).

**Table 2. Shoreline datasets used in compiling the Fort Bragg DEM**

| *Source* | *Year* | *Data Type* | *Spatial Resolution* | *Original Horizontal Datum/Coordinate System* | *Original Vertical Coordinate System* | *URL* |
|---|---|---|---|---|---|---|
| NGDC | 2011 | Composite vectorized hydraulic breaklines | Not defined | NAD 83 geographic | MHW | N/A |
| NGDC | 2011 | Digitized vector Coastline | Not defined | World Geodetic System (WGS) 84 geographic | MHW | N/A |

[2]The horizontal difference between the North American Datum of 1983 (NAD 83) and World Geodetic System of 1984 (WGS 84) geographic horizontal datums is approximately one meter across the contiguous U.S., which is significantly less than the cell size of the DEM. Many GIS applications treat the two datums as identical, so do not actually transform data between them, and the error introduced by not converting between the datums is insignificant for our purposes. NAD 83 is restricted to North America, while WGS 84 is a global datum. As tsunamis may originate most anywhere around the world, tsunami modelers require a global datum, such as WGS 84 geographic, for their DEMs so that they can model the waves passage across ocean basins. This DEM is identified as having a WGS 84 geographic horizontal datum even though the underlying elevation data were typically transformed to NAD 83 geographic. At the scale of the DEM, WGS 84 and NAD 83 geographic are identical and may be used interchangeably.

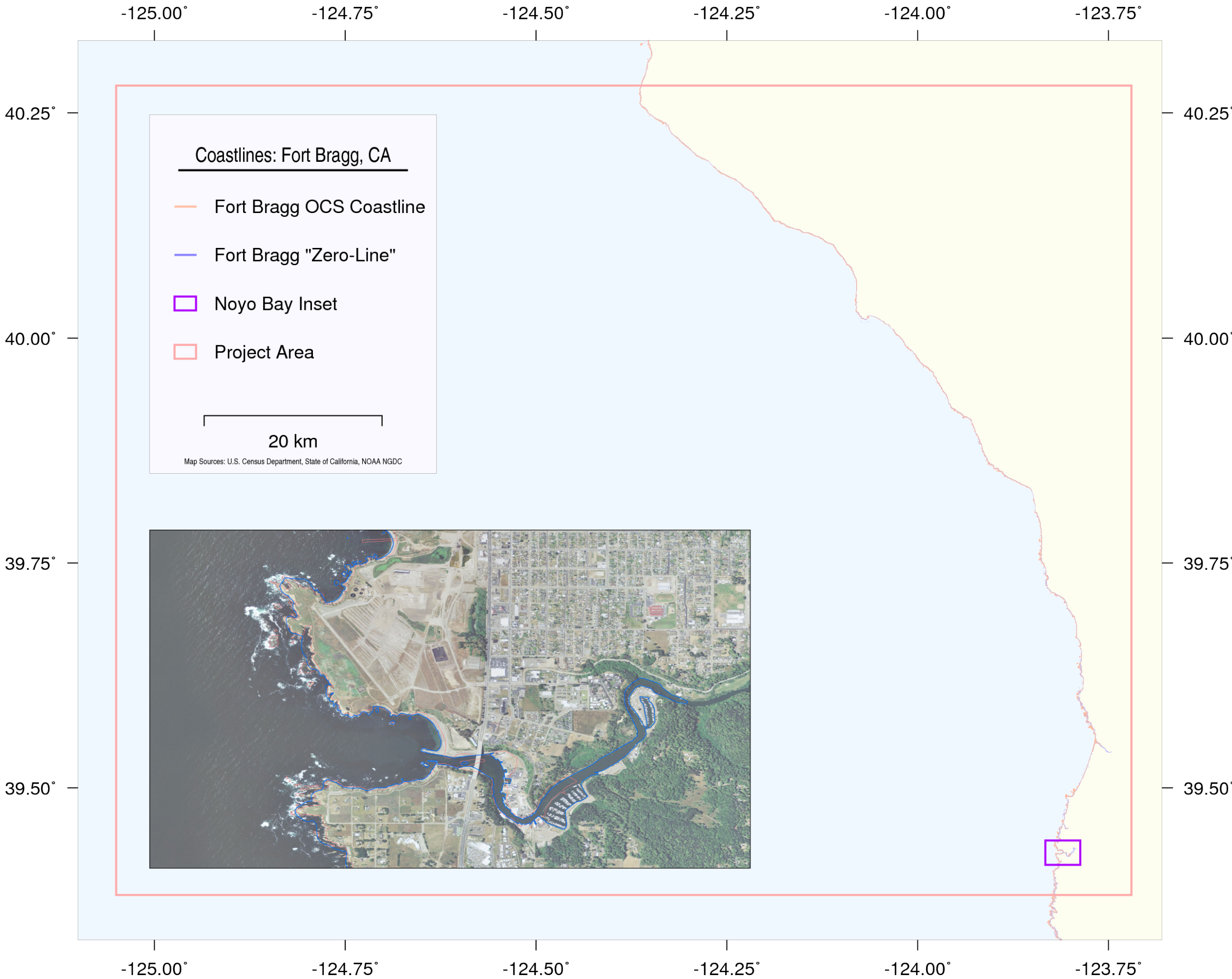


**Figure 4.** *Fort Bragg region coastline, including an inset of Noyo Bay where NGDC digitized the coastline to aerial imagery.*

### 3.1.2 Bathymetry

Bathymetric datasets available in the Fort Bragg region included 50 NGDC multibeam sonar surveys, six National Ocean Survey (NOS) high-resolution surveys in Bathymetric Attributed Grid (BAG) format, and 38 NOAA NOS Hydro surveys (Table 3; Figure 3). NGDC evaluated but did not use the OCS Electronic Nautical Charts (ENCs) that were available from OCS due to conflicts with the other bathymetric surveys.

**Table 3. Bathymetric datasets used in compiling the Fort Bragg DEM**

| *Source* | *Year* | *Data Type* | *Spatial Resolution* | *Original Horizontal Datum/Coordinate System* | *Original Vertical Coordinate System* | *URL* |
|---|---|---|---|---|---|---|
| NGDC | 2011 | Multibeam soundings | N/A | NAD 83 geographic | Assumed mean sea level (MSL) | http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html |
| NOS BAG | 2008–2009 | Soundings | N/A | NAD 83 geographic | mean lower low water (MLLW) | N/A |
| NOS Hydro | 1925 - 1985 | Soundings | N/A | NAD 83 geographic | MLLW | http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html |

**1) NGDC Multibeam**

Fifty multibeam swath sonar surveys were available from the NGDC multibeam database for use in the development of the Fort Bragg DEM (Figure 3). This database is comprised of the original swath sonar files of surveys conducted mostly by the U.S. academic fleet. All surveys have a horizontal datum of WGS 84 geographic and an undefined vertical datum, assumed to be equivalent to NAVD 88. The data were gridded to 1 arc-second resolution using MB-System and xyz data were transformed to MHW using a conversion grid.

**2) NOS/BAG Hydrographic Surveys**

A total of six NOS high-resolution hydrographic surveys, in BAG format, were conducted between 2008 and 2009 and were available for use in the development of the Fort Bragg DEMs (Fig. 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic.

**3) NOS Hydrographic Surveys**

A total of 38 NOS hydrographic surveys were available for use in the development of the Fort Bragg DEMs (Figure 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic.

### *3.1.3 Topography–Bathymetry*

The topography–bathymetry data used to build the Fort Bragg DEM include high-resolution coastal lidar survey data from the Airborne Lidar Assessment of Coastal Erosion (ALACE) Coastal Topography-Bathymetry Lidar; (Table 4; Figure 3).

**Table 4. Topography–Bathymetry dataset used in compiling the Fort Bragg DEM**

| *Source* | *Year* | *Data Type* | *Spatial Resolution* | *Original Horizontal Datum/Coordinate System* | *Original Vertical Coordinate System* | *URL* |
|---|---|---|---|---|---|---|
| NASA/USGS | 1999–2000 | Bare-earth lidar | 1 - 5 meters | WGS 84 geographic | MLLW | http://www.csc.noaa.gov/ |

**1) NASA/USGS Airborne LiDAR Assessment of Coastal Erosion (ALACE) Topography–Bathymetry**

Coastal lidar surveys of California were conducted in 2002 as part of an effort by the USGS and National Aeronauts and Space Administration (NASA) to map beach topography and assess beach change for the states of California, Oregon and Washington. The surveys used a pulsed laser ranging system mounted onboard an aircraft to measure ground elevation and coastal topography. The laser emits laser beams at high frequency and is directed downward at the earth's surface through a port opening in the bottom of the aircraft's fuselage. The laser system records the time difference between emission of the laser beam and the reception of the reflected laser signal in the aircraft. The aircraft travels over the beach at approximately 60 meters per second while surveying from the low water line to the landward base of the sand dunes.

### 3.1.4 Topography

The topographic dataset used to build the Fort Bragg DEM was the US Geological Society (USGS) National Elevation Dataset (NED) 1/3 arc-second DEM (Table 5; Figure 3).

**Table 5. Topographic dataset used in compiling the Fort Bragg DEM**

| *Source* | *Year* | *Data Type* | *Spatial Resolution* | *Original Horizontal Datum/Coordinate System* | *Original Vertical Coordinate System* | *URL* |
|---|---|---|---|---|---|---|
| USGS | 2011 | Bare-earth DEM | 1 - 5 meters | WGS 84 geographic | NAVD88 | N/A |

1) **USGS NED 1/3 arc-second DEM** The USGS NED provides complete 1/3 arc-second coverage of northern California. Data are in NAD 83 geographic coordinate and assumed MSL vertical datum (meters), and are available for download as raster DEMs. The bare-earth elevations have a vertical accuracy of +/- 7 to 15 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov). The dataset was derived from USGS quadrange maps and aerial photographs based on topographic surveys; it has been revised using data collected in 1999. The NED DEMs were transformed to NAD 83 and MHW using a conversion grid (Section 3.2.2; Figure 6). The gridded data were evaluated and positive elevations over open water were removed by clipping the data to the coastline using *GDAL* and *Python*. The resulting data were converted to xyz data using *GDAL*.

## 3.2 Establishing Common Datums

### *3.2.1 Vertical Datum Transformations*

Datasets used in the compilation and evaluation of the Fort Bragg DEM were originally referenced to MLLW or NAVD 88. All datasets were transformed to MHW using a conversion grid developed using NOAA's *VDatum* software. (Section 3.2.2; Figs. 5 & 6).

- **Bathymetric Data:** All hydrographic surveys were transformed from MLLW or NAVD 88 to MHW using a conversion grid.
- **Topographic–Bathymetric Data:** All topographic–bathymetric datasets used in the compilation of the Fort Bragg DEM originated in NAVD 88 vertical datum and were transformed to MHW using a conversion grid.
- **Topographic Data:** All topographic datasets used in the compilation of the Fort Bragg DEM originated in NAD 88 vertical datum and were transformed to MHW using a conversion grid.

### *3.2.2 Developing the conversion grid*

Using extents slightly larger (∼5%) than the Fort Bragg project area, an initial *xyz* file was created that contained the coordinates of the four bounding vertices and midpoint of the larger extents. The elevation value at each of the points was set to zero. The GMT command 'surface' applied a tension spline to interpolate cell values making a zero-value 3 arc-second grid. This "zero-grid" was then converted to an intermediate *xyz* file using the GMT command 'grd2xyz'. Conversion values from NAVD 88 to MHW and MLLW to MHW at each *xyz* point were generated using *VDatum* and the null values were removed.

The median-averaged *xyz* file was then interpolated with the GMT command 'surface' to create the 1/3 arc-second 'NAVD 88 to MHW' and 'MLLW to MHW' conversion grids with the extents of the buffered Fort Bragg project area, representing the differences between the datums onshore to the DEM extents (Figures 5 & 6).

### *3.2.3 Assessing accuracy of conversion grid*

The conversion grids were assessed using the NOS survey data. For testing of this methodology, the NOS hydrographic survey data were transformed from MLLW to NAVD 88 using *VDatum*. The resultant *xyz* files were filtered to remove any null values and then were merged together to form a single *xyz* file of the NOS hydrographic survey data with a vertical datum of NAVD 88. A second *xyz* file of NOS data was created with a vertical datum of MHW using the same method. Elevation differences between the MHW and NAVD 88 *xyz* files were computed. The same method was used to assess the 'MLLW to MHW' conversion grid.

To verify the conversion grid methodology, the difference *xyz* file was used to generate a histogram using Gnuplot[3] to evaluate the performance of the 1/3 arc-second conversion grids by comparing 'NAVD 88 to MHW' and 'MLLW to MHW' conversion grids to the combined difference *xyz* files from the *VDatum* project area (Figure 7).

[3]Gnuplot is an open-source command-driven interactive function plotting program. It can be used to plot functions and data points in both two- and three-dimensional plots in many different formats. It is designed primarily for the visual display of scientific data.

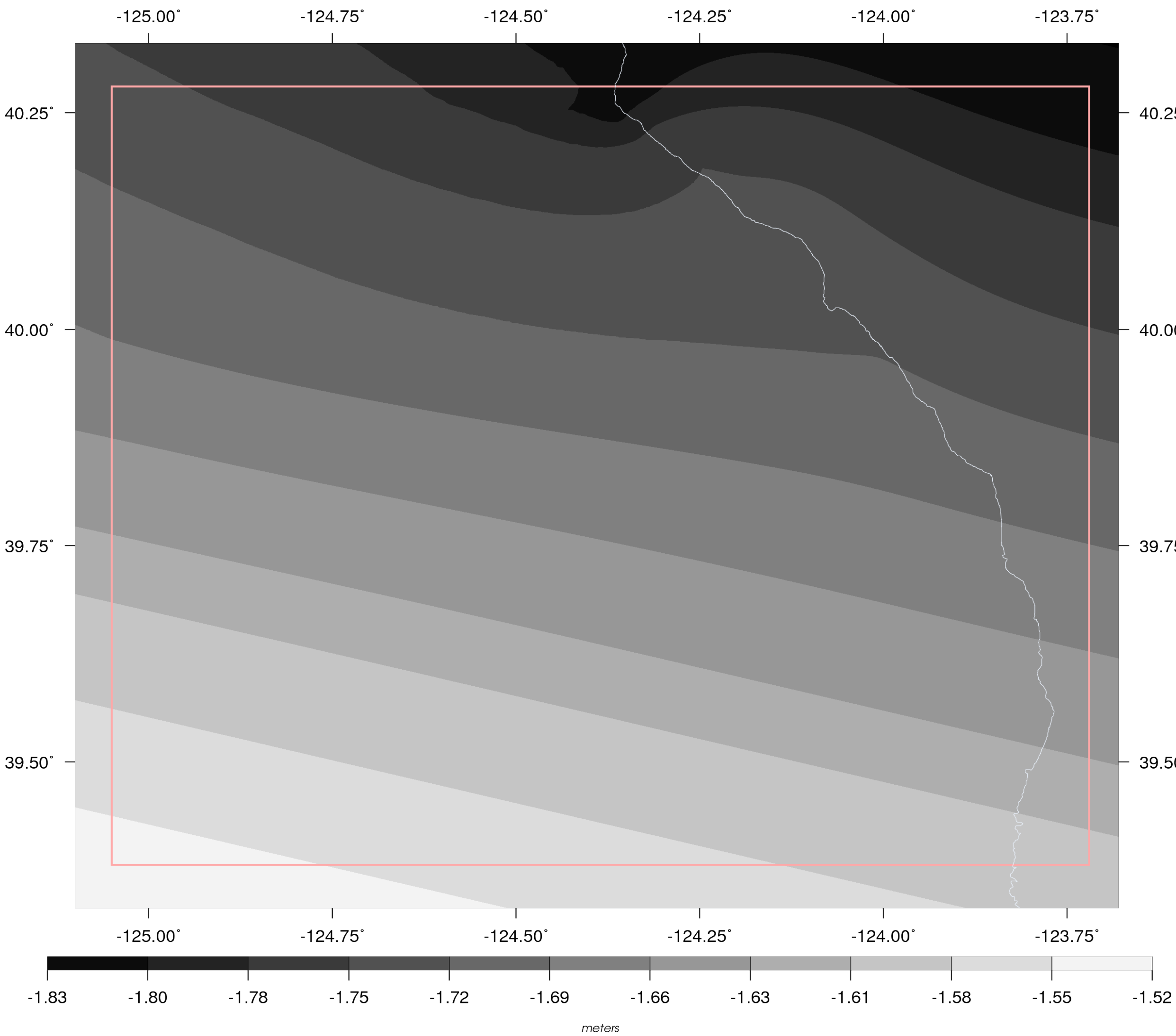


**Figure 5.** *MLLW to MHW Conversion Grid of the Fort Bragg DEM. Values equal the difference between MLLW and MHW.*

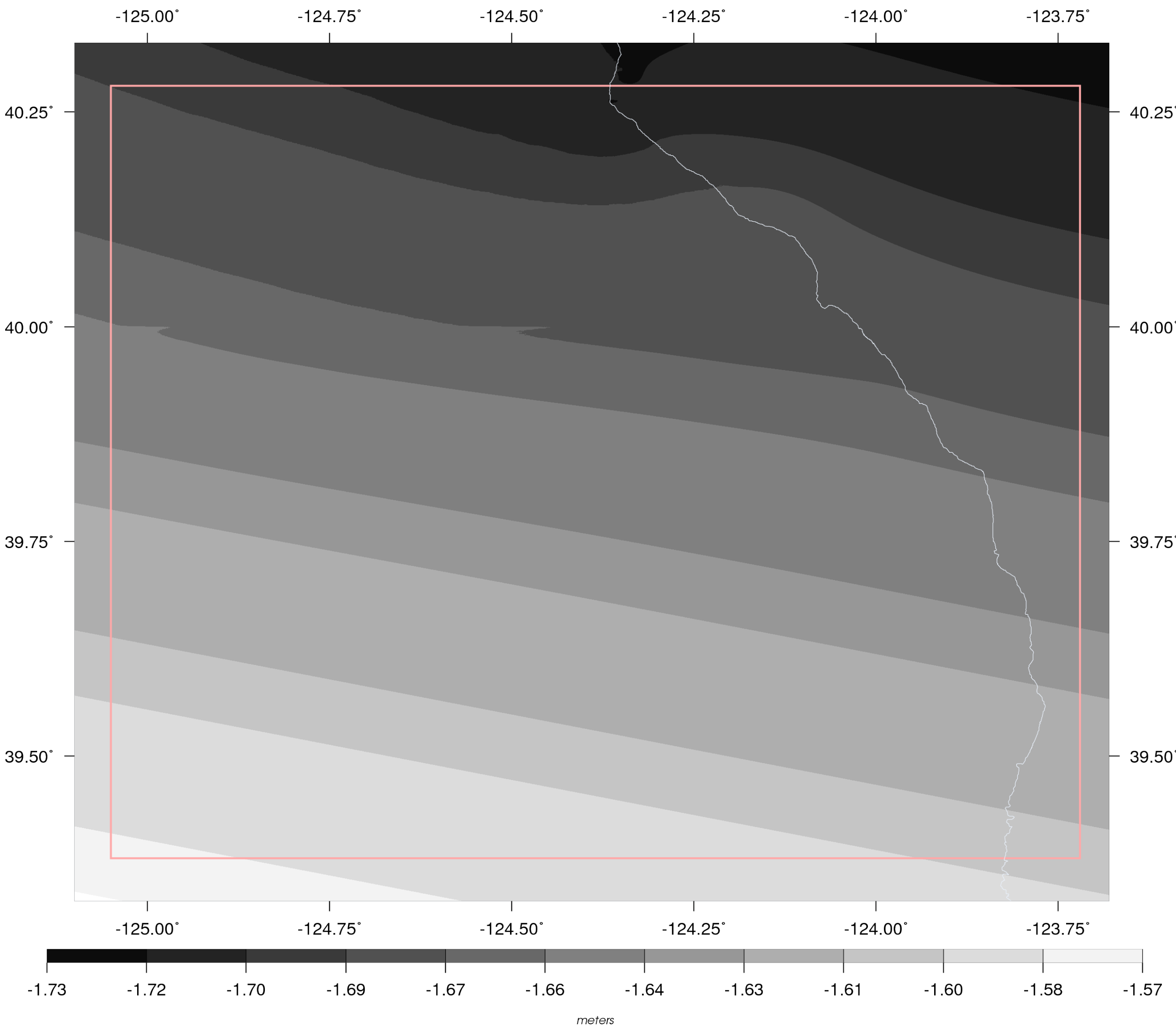


**Figure 6.** *NAVD 88 to MHW Conversion Grid of the Fort Bragg DEM. Values equal the difference between NAVD 88 and MHW.*

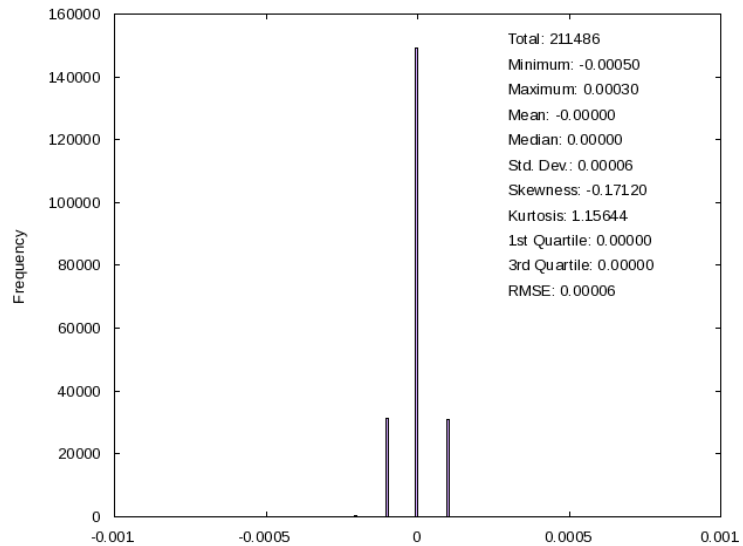


**Figure 7.** *Histogram of the differences between the conversion grid and xyz difference files using NOS hydrographic survey data.*

### *3.2.4 Horizontal Datum Transformations*

Datasets used to build the Fort Bragg DEM were downloaded or received referenced to WGS 84 geographic or NAD 83 geographic horizontal datums. The relationship transformational equations between these horizontal datums are well established. Data were transformed to a horizontal datum of NAD 83 geographic using *Proj4*.[4]

## 3.3 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the ascii *xyz* files were reviewed for consistency between datasets. Problems and errors were identified and resolved before proceeding with subsequent gridding steps.

[4] *Proj4* is a free standard Unix filter function which converts geographic longitude and latitude coordinates into cartesian coordinates, $(\lambda, \phi) \rightarrow (x, y)$, by means of a wide variety of cartographic projection functions. http://trac.osgeo.org/proj/

# 4. DEM DEVELOPMENT

## 4.1 Smoothing of bathymetric data

The NGDC multibeam hydrographic survey data are generally sparse relative to the resolution of the 1/3 arc-second Fort Bragg DEM. This is especially true for deep water surveys in the Pacific and shallow water surveys in bays where data have point spacing up to 350 meters apart. In order to reduce artifacts created in the DEM by the low-resolution bathymetric datasets, and to provide effective interpolation in the deep water and into the coastal zone, a 1/3 arc-second pre-surface bathymetric grid was generated using Generic Mapping Tools (*GMT*)[5]. The coastline elevation value was set at 0 meters to ensure a bathymetric surface below zero in areas where data are sparse or non-existent.

The point data were median-averaged using the *GMT* command "blockmedian" to create a 1/3 arc-second grid 0.05 degrees (∼5%) larger than the Fort Bragg DEM gridding region. The *GMT* command 'surface' was then used to apply a tight spline tension to interpolate elevations for cells without data values. The *GMT* grid created by 'surface' was converted to an *ESRI* Arc ASCII grid file, and clipped to the final coastline (to eliminate data interpolation onto land areas) using *GDAL* and *Python*. The resulting surface was exported as an *xyz* file for use in the final gridding process (Table 6).

## 4.2 Building the MHW DEM

MB-System[6] was used to create the 1/3 arc-second Fort Bragg DEM. The MB-System command 'mbgrid' was used to apply a tight spline tension to the *xyz* data, and interpolate values for cells without data. The data hierarchy used in the 'mbgrid' gridding algorithm, as relative gridding weights, is listed in Table 6. The resulting binary grid was converted to an Arc ASCII grid using the MB-System tool 'mbm_grd2arc' to create the final 1/3 arc-second Fort Bragg DEM. Figure 8 illustrates cells in the DEM that have interpolated values versus data contributing to the cell value.

**Table 6. Data hierarchy used to assign gridding weight in MB-System**

| ***Dataset*** | ***Relative Gridding Weight*** |
|---|---|
| NOS BAG | 50 |
| USGS NED | 20 |
| CSC bathymetric-topographic lidar | 10 |
| NGDC Multibeam | 5 |
| NOS Hydro | 5 |
| Pre-surfaced bathymetric grid | 1 |

[5] *GMT* is an open source collection of ∼60 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. *GMT* supports ∼30 map projections and transformations and comes with support data such as GSHHS coastlines, rivers, and political boundaries. *GMT* is developed and maintained by Paul Wessel and Walter H. F. Smith with help from a global set of volunteers, and is supported by the National Science Foundation. It is released under the GNU General Public License. URL: http://gmt.soest.hawaii.edu/ [Extracted from *GMT* web site.]

[6] MB-System is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multibeam, interferometry, and sidescan sonars. The source code for MB-System is freely available (for free) by anonymous ftp (point and access through these web pages). A complete description is provided in web pages accessed through the web site. MB-System was originally developed at the Lamont-Doherty Earth Observatory of Columbia University (L-DEO) and is now a collaborative effort between the Monterey Bay Aquarium Research Institute (MBARI) and L-DEO. The National Science Foundation has provided the primary support for MB-System development since 1993. The Packard Foundation has provided significant support through MBARI since 1998. Additional support has derived from SeaBeam Instruments (1994–1997), NOAA (2002–2004), and others. URL: http://www.ldeo.columbia.edu/res/pi/MB-System/ [Extracted from MB-System web site.]

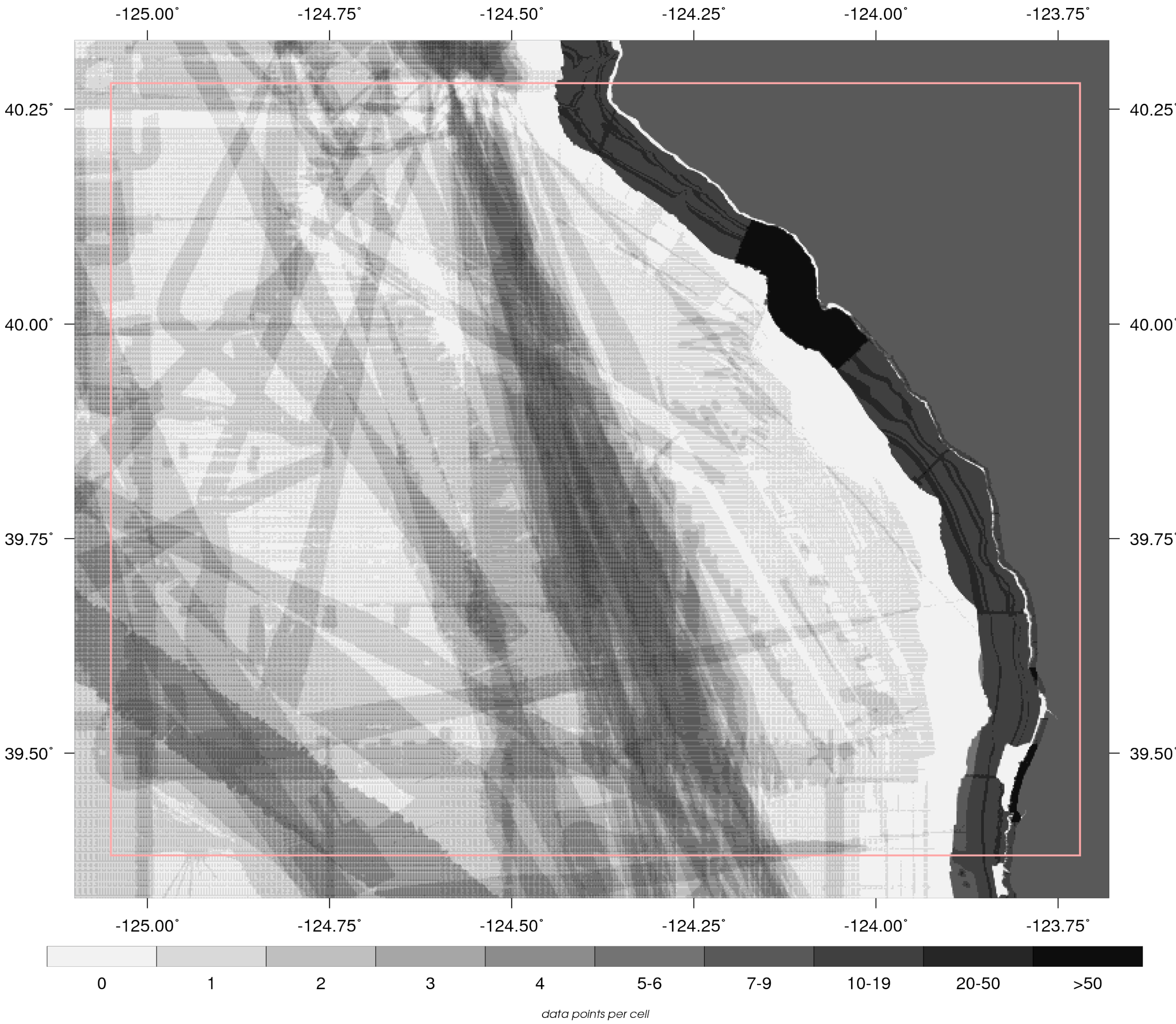


**Figure 8.** *Data density of the Fort Bragg gridding region.*

## 4.3 Building the NAVD 88 DEM

The Fort Bragg NAVD 88 DEM was created as a result of combining the 'NAVD 88 to MHW' conversion grid (Figure 6) with the MHW DEM.

## 4.4 Quality Assessment of the structured DEM

### *4.4.1 Horizontal accuracy*

The horizontal accuracy of topographic and bathymetric features in the Fort Bragg DEM is dependent upon the datasets used to determine corresponding DEM cell values and the cell size of the DEM, making the highest accuracy possible 1/3 arc-seconds (about 10 meters). The horizontal accuracy is 10 meters where topographic IfSAR datasets contribute to the DEM cell value. The horizontal accuracy is 0.75 meters at 1 sigma where bathymetric–topographic lidar-derived data contributes to the DEM cell value. Bathymetric features are resolved only to within a few tens of meters in deep-water areas. Shallow, near-coastal regions, rivers, and harbor surveys have an accuracy approaching that of sub aerial topographic features. Positional accuracy is limited by: the sparseness of deep-water soundings; and by the morphologic change that occurs in this dynamic region.

### *4.4.2 Vertical accuracy*

Vertical accuracy of the Fort Bragg DEM is also highly dependent upon the source datasets contributing to DEM cell values. Topographic lidar has an estimated RMSE of 13.9 to 20 cm. Bathymetric-topographic lidar-derived data have a vertical accuracy of 0.20 meters at 1 sigma. Bathymetric areas have an estimated accuracy of between 0.1 meters and 5% of water depth.

### *4.4.3 Slope maps and 3D perspectives*

*GMT* was used to generate a slope grid from the Fort Bragg DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (Figure 9). The DEM was transformed to projected coordinates (horizontal units in meters) using *GMT* for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Analysis of preliminary grids revealed suspect data points, which were corrected before recompiling the DEM. Figure 10 shows a perspective view image of the 1/3 arc-second Fort Bragg in its final version.

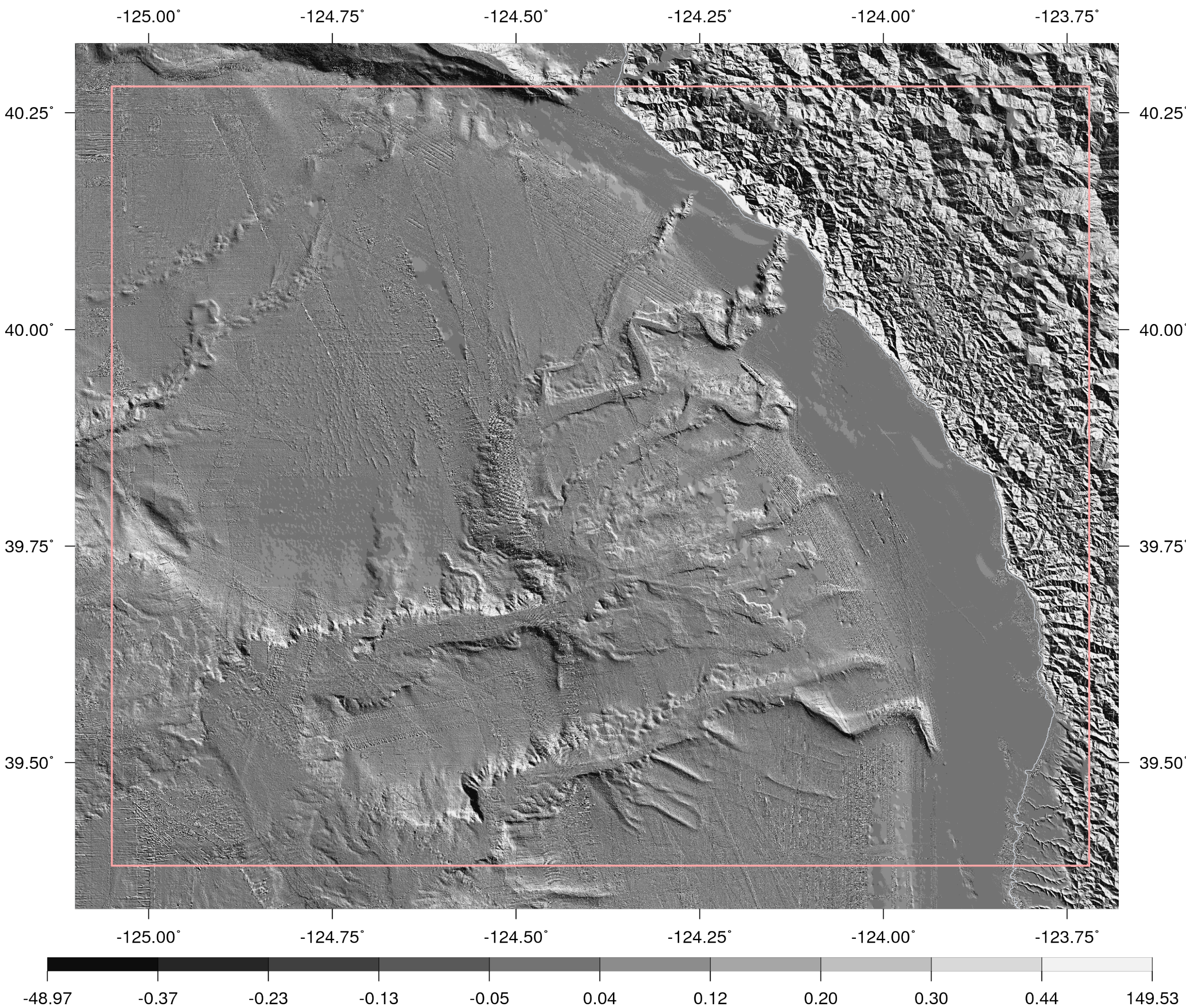


**Figure 9.** *Slope map of the Fort Bragg DEM*

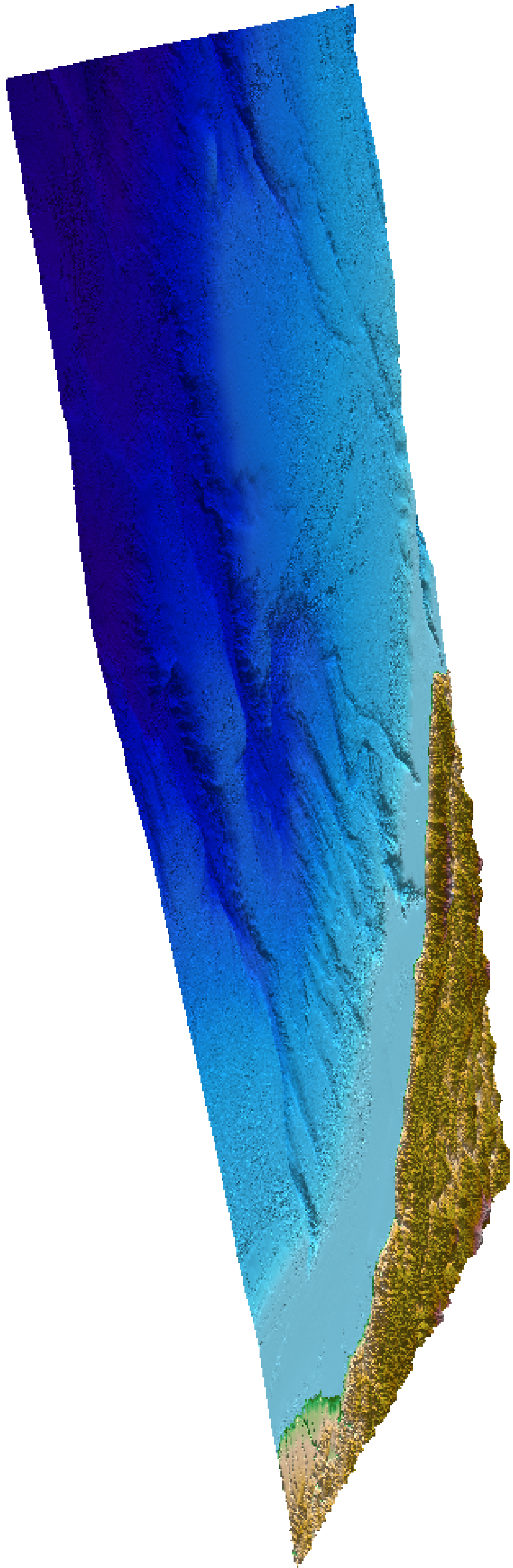

**Figure 10.** *Perspective view from the southwest of the Fort Bragg DEM.*

### 4.4.4 *Comparison with NGS geodetic monuments*

The elevations of 540 NOAA National Geodetic Survey (NGS) geodetic monuments (Figure 11) were extracted from online shapefiles of NGS geodetic monument datasheets (http://www.ngs.noaa.gov/cgi-bin/datasheet.prl), which give monument positions in NAD 83 geographic (typically sub-mm accuracy) and elevations in North American Vertical Datum (NAVD) 88. Monument elevations were transformed to MHW using a NAVD 88 to MHW conversion grid and were compared with elevations in the Fort Bragg MHW DEM. Differences between the DEM elevations and the NGS geodetic monument elevations range from -32.85 to 51.72 meters, with the majority of them being within +/-1 meter (Figure 12). Negative values indicate that the monument elevation is less than the DEM elevation. After examination, it was determined that those monuments with the largest deviations do not represent ground surface as they are located on top of an observation tower, light house or at the apex of other structures.

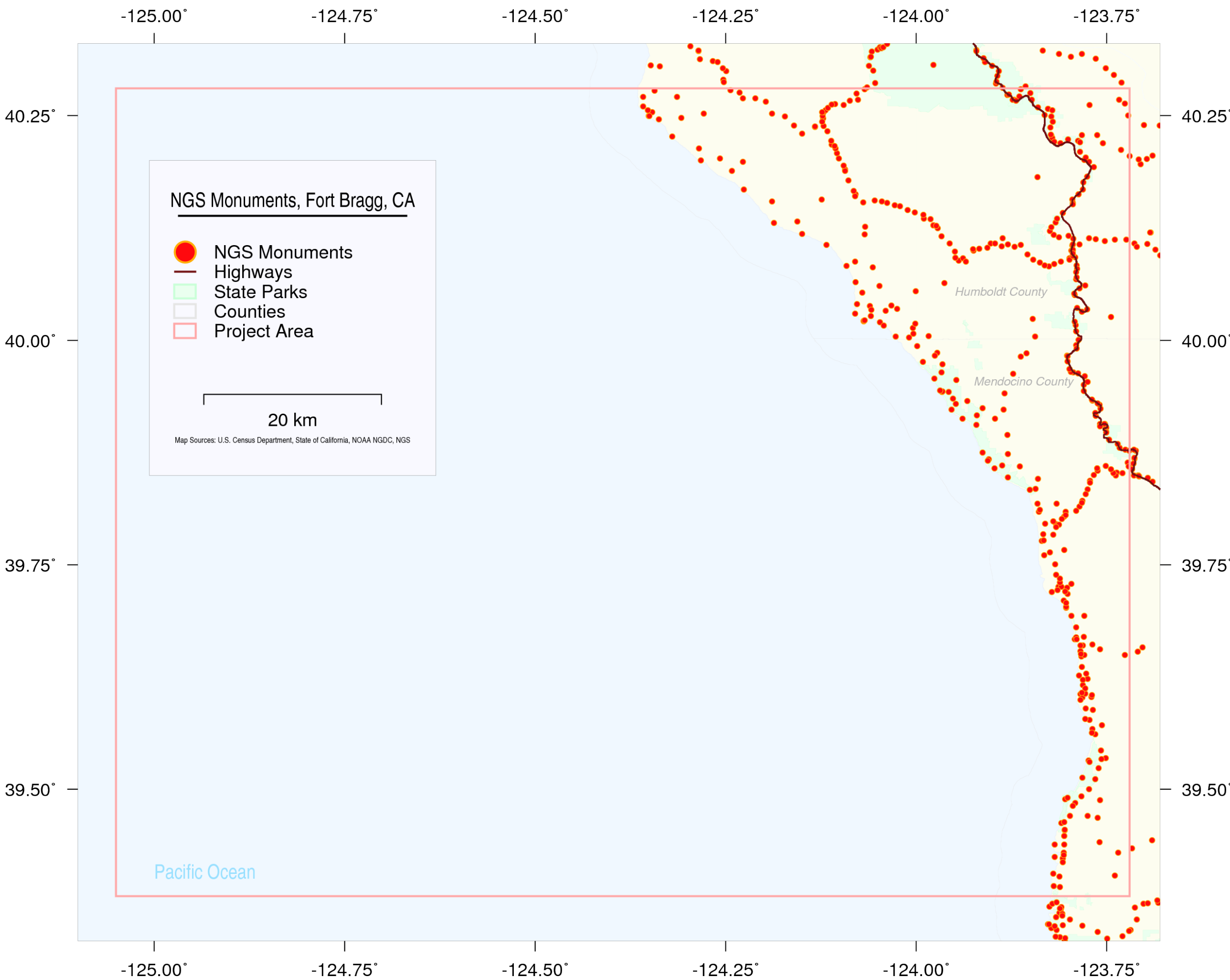


**Figure 11.** *Locations of NGS monuments used in the evaluation of the Fort Bragg DEM.*

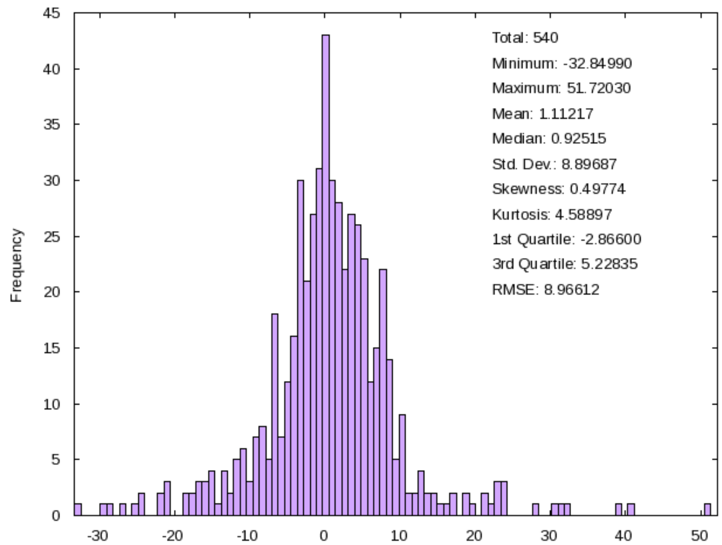


**Figure 12.** *Histogram of the differences between the NGS monument elevation values and the Fort Bragg DEM*

## 5. Summary and Conclusions

Two bathymetric–topographic structured digital elevation models of the Fort Bragg, CA region, with cell spacing of 1/3 arc-second, and a vertical datum of MHW and NAVD 88 were developed by NGDC for PMEL for use in tsunami generation, propogation and inundation simulations.

Recommendations to improve the Fort Bragg DEM, based on NGDC's research and analysis, are listed below:

- Conduct publically available lidar surveys of all topographic regions.
- Conduct publically available high-resolution surveys of all harbors and bays.

## 6. Acknowledgements

The creation of the Fort Bragg DEM was funded by NOAA PMEL. The authors thank Nazila Merati, Marie Eble and Vasily Titov (PMEL).

## 7. References

Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, 2003. Federal Emergency Management Agency, Flood Hazard Mapping Program.

## 8. Data Processing Software

**ArcGIS 10,** developed and liscensed by ESRI, Redlands, California, http://www.esri.com

**ESRI World Imagery** - ESRI ArcGIS Resource Centers, http://www.esri.com

**GEODAS v. 5** - Geophysical Data System, free software developed and maintained by Dan Metzger, NOAA National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/geodas

**GMT v. 4.1.4** - Generic Mapping Tools, free software developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, http://gmt.soest.hawaii.edu

**MB-System v. 5.1.0,** free software developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, http://www.ldeo.columbia.edu/res/pi/MB-System

**Quick Terrain Modeler v. 6.0.1,** lidar processing software developed by John Hopkins University's Applied Physics Laboratory (APL) and maintained and licensed by Applied Imagery, http://www.appliedimagery.com

**GDAL v. 1.8.0** Geographic Data Abstraction Library is a translator library maintained by Frank Warmerdam, http://gdal.org

**Proj4 v. 4.7.0** free software developed by Gerald Evenden and maintained by Frank Warmerdam, http://trac.osgeo.org/proj/

**VDatum v. 2.3** developed and maintained by NOAAs National Geodetic Survey (NGS), Office of Coast Survey (OCS), and Center for Operational Oceanographic Products and Services (CO-OPS), http://vdatum.noaa.gov/

# A. Source Bathymetry Data

**Table A-1. NOS Hydrographic datasets used in building the Northern Gulf Coast DEMs**

| *Survey ID* | *Year* | *Scale/Vertical Accuracy* | *Original Vertical Datum* | *Provided Horizontal Datum* |
|---|---|---|---|---|
| B00001 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00002 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00003 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00004 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00005 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00006 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00007 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00008 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00009 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00010 | 1984 | 50,000 | MLLW | North American Datum 1983 |
| B00013 | 1985 | 50,000 | MLLW | North American Datum 1983 |

Table A-1 – Continued

| ***Survey ID*** | ***Year*** | ***Scale/Vertical Accuracy*** | ***Original Vertical Datum*** | ***Provided Horizontal Datum*** |
|---|---|---|---|---|
| B00014 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00015 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00032 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00035 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00036 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00037 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| B00038 | 1985 | 50,000 | MLLW | North American Datum 1983 |
| H04982 | 1929 | 20,000 | Mean Lower Low Water | North American Datum 1983 |
| H04983 | 1929 | 20000/10000 | Mean Lower Low Water | North American Datum 1983 |
| H04984 | 1929 | 20000/10000 | Mean Lower Low Water | North American Datum 1983 |
| H04989 | 1929 | 40,000 | Mean Lower Low Water | North American Datum 1983 |

Table A-1 – Continued

| ***Survey ID*** | ***Year*** | ***Scale/Vertical Accuracy*** | ***Original Vertical Datum*** | ***Provided Horizontal Datum*** |
|---|---|---|---|---|
| H04991 | 1929 | 120,000 | Mean Lower Low Water | North American Datum 1983 |
| H05920 | 1935 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H05921 | 1935 | 40,000 | Mean Lower Low Water | North American Datum 1983 |
| H05944 | 1935 | 40,000 | Mean Lower Low Water | North American Datum 1983 |
| H05945 | 1935 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H05956 | 1935 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H06135 | 1935 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H06138 | 1936 | 40,000 | Mean Lower Low Water | North American Datum 1983 |
| H06161 | 1936 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H06162 | 1936 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H06163 | 1936 | 10,000 | Mean Lower Low Water | North American Datum 1983 |

Table A-1 – Continued

| ***Survey ID*** | ***Year*** | ***Scale/Vertical Accuracy*** | ***Original Vertical Datum*** | ***Provided Horizontal Datum*** |
|---|---|---|---|---|
| H06164 | 1936 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H06221 | 1938 | 40,000 | Mean Lower Low Water | North American Datum 1983 |
| H06222 | 1937 | 10,000 | Mean Lower Low Water | North American Datum 1983 |
| H08567 | 1960 | 160,000 | Mean Lower Low Water | North American Datum 1983 |